RESEARCH HIGHLIGHTS

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HEALTHY HIGH-RISE: A GUIDE TO INNOVATION IN THE DESIGN AND CONSTRUCTION OF HIGH-RISE RESIDENTIAL BUILDINGS

Introduction

High-rise residential buildings play an important role in housing Canadians. They range from affordable units for low-income households through to luxury housing in some of Canada's most prestigious locations. An estimated 20 per cent of Canadians live in high-rise buildings.

While the benefits of such housing are generally considerable—such as proximity to services and public transportation, efficient use of land and infrastructure—high-rises have not kept pace with recent technological advances. Common inadequacies include:

- water penetration and air leakage through the building envelope, resulting in structural and other damage, high energy costs and occupant discomfort
- inadequate thermal envelope performance and thermal bridging, resulting in occupant discomfort and high energy costs
- heating, ventilation and air conditioning (HVAC) systems strongly affected by wind pressure and building stack effects, resulting in occupant discomfort and poor indoor air quality
- changes in land use that impact on stormwater flow
- occupant dissatisfaction with noise levels
- lack of accessibility for people with disabilities.

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Warranty programs have covered many repair costs, but this has depleted their reserves. Developers are now increasingly expected to bear the cost of remedial repairs and replacement of deteriorating components.

Researchers, architects and engineers agree that better high-rise buildings can be constructed. Improving performance requires changes in the design and construction process, more comprehensive and improved detailing, enhanced quality control and commissioning processes, improved operation and maintenance procedures, and thinking of the building as a whole, from construction through operation.

During the 1990s, building scientists, researchers and practitioners invested considerable effort in developing improved design and construction procedures to address typical problems encountered in high-rise residential buildings. They found ways to upgrade parking garages, enhance envelope durability and improve a multi-unit building's thermal envelope, HVAC systems, accessibility and environmental performance.

The outcome of their work is summarized in a guidebook produced by Canada Mortgage and Housing Corporation, *Healthy High-Rise: A Guide to Innovation in the Design and Construction of High-Rise Residential Buildings*. The guidebook is unique in its overview of high-rise building problems arising from conventional practices. It provides insight into building science principles by exploring key issues associated with various design aspects. It then presents design considerations for improving building performance, identifies retrofit opportunities and discusses regional differences.

The guide emphasizes the need for a holistic, integrated approach in designing and constructing high-rises. Typically, the various disciplines and trades involved in these processes operate independently of one another. It is thought that improvements in durability, efficiency, comfort and aesthetics could be achieved without cost surcharges if all disciplines readily collaborated in developing buildings as systems.

Sources of high-rise problems

The introduction briefly discusses common sources of high-rise building failures, these being design and construction deficiencies, lack of proper commissioning and testing, and shortcomings with respect to operational and maintenance instruction. This section also touches on the significance of air and moisture movement and the impact they can have on buildings.

Design and construction deficiencies

Researchers are able to draw a direct correlation between the limitations of project designs and problems found in high-rise buildings. Inadequate and incorrect detailing is a common problem, and the rationale for specific details is often poorly communicated to the field.

Even where plans and specifications are excellent, problems can arise. Specified materials are frequently substituted with ones that are not compatible. Manufacturers' installation requirements are not always followed, and training and quality control measures can fall short. An integrated project team approach would help to avoid such problems and improve building performance by ensuring that construction meets the specified requirements.

Commissioning and operating

Non-existent or inadequate commissioning and testing protocols are another source of problems. All too often, problems are identified at a late stage in the construction process, or after a building has been occupied, requiring costly remedial work. Failure to detect construction defects increases costs to both owners and operators. Mock-up testing of typical sample assemblies is an essential tool for ensuring a project will operate as intended. Usually, the cost of testing pays for itself during the construction period, as well as saving costs afterwards.

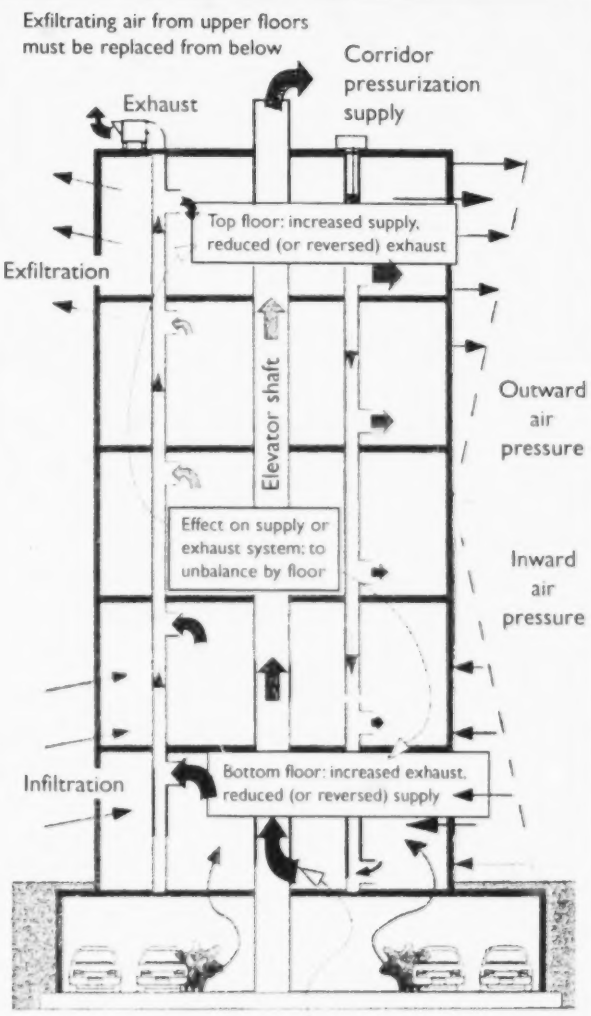
When buildings are turned over to owners and property managers, design and construction teams often do not clearly communicate the operating and maintenance requirements. Operation manuals need to be provided and staff need to be trained in performing regular maintenance to minimize costly remedial and repair work and to ensure efficient functioning of all building systems.

Air and moisture: impact on performance

Most problems in high-rise residential buildings result from the interplay between movement of air, moisture and heat. Winds can exert significant pressures, forcing air into a building and drawing it out through leaks and cracks in the building envelope. The effect of air leakage on building performance is significant. It can cause considerable occupant discomfort and contribute to deterioration of buildings through moisture damage.

In winter, the vertical air movement of stack effect results in cooler air entering the lower levels of a building and rising as it warms. The taller the building and the greater the temperature difference between the inside and outside, the greater the stack pressure. Lower levels tend to be underheated, while upper levels are overheated. This effect can also cause backdrafting and uncontrolled smoke movement during fires.

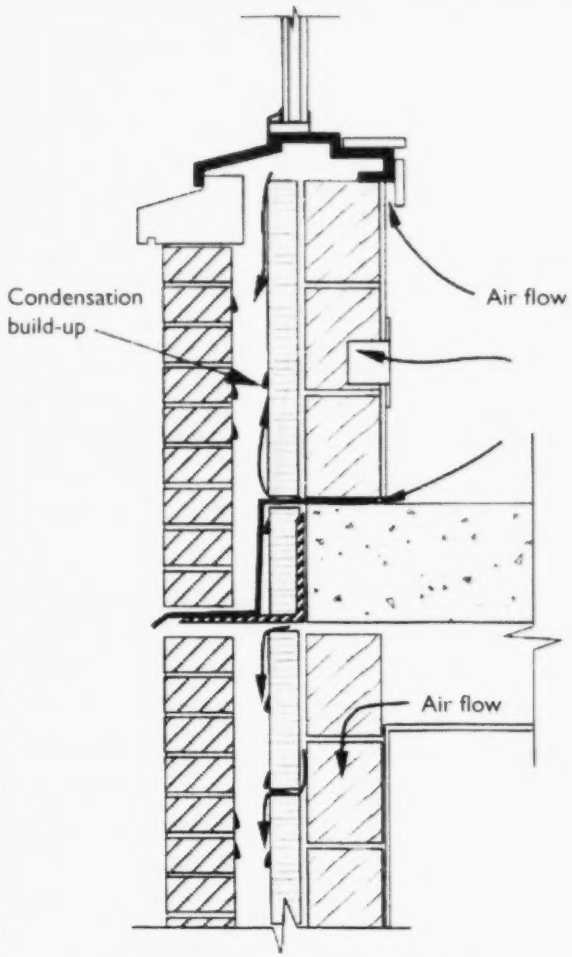
Figure 1. Air movement in buildings in winter


Exfiltrating air from upper floors must be replaced from below
Corridor pressurization supply
Exhaust
Top floor: increased supply, reduced (or reversed) exhaust
Exfiltration
Elevator shaft
Outward air pressure
Effect on supply or exhaust system: to unbalance by floor
Inward air pressure
Infiltration
Bottom floor: increased exhaust, reduced (or reversed) supply
Potential for leakage of gases from garage into building, if garage fans are left off
Heated air rises taking the easiest path (such as elevator shafts, garbage chutes, etc.)

Tightening the building envelope helps counter the movement of air caused by the stack effect. It prevents moisture migration into and out of the building envelope, improves occupant comfort and reduces energy costs. It allows for the integration of smaller, more appropriately sized mechanical systems, which also reduces operating costs.

Moisture can result in the deterioration of building cladding systems over time and cause other structural damage. Cracks and penetrations in the building envelope provide opportunities for moisture or water penetration, which can lead to mold and rot within the walls, as well as more visible damage. Key means for protecting against moisture and water damage in high-rise buildings include improved detailing and construction procedures, shedding water away from the building envelope, pressure-equalized rainscreen wall systems and improved air leakage control.

Figure 2. Typical problems



Condensation from moist air exfiltrating if effective barrier not in place.

Designing better high-rises

The main sections of the guide deal with enhancing high-rise residential building performance in the following areas:

- envelope design
- energy performance
- indoor air quality
- environmental performance
- accessibility
- green infrastructure.

Within each section, the guide explores issues and design considerations pertinent to a range of topics in an easy-to-read format, and illustrations enhance the text throughout. Case studies in most sections provide additional information and insight with respect to practical applications.

The sections include charts cross-referencing a given topic to other related topics in the guide. Each section also includes references to recent research and development studies. These studies provide more detailed and technical information on various aspects of high-rise construction and operation.

The first section, "Enhancing Envelope Design", looks at air barriers, wetting of building envelopes, pressure-equalized rainscreens, exterior insulation and finish systems (EIFS), parking garages and low-slope roofing systems.

Section 2, "Enhancing Energy Performance", focuses on the building envelope, space heating and air conditioning, other systems (control systems, individual suite metering, motors, auxiliary electric motors and domestic hot water heating), lighting and appliances and alternative energy supply systems.

Discussion of issues and solutions related to source reduction and mechanical ventilation comprise section 3, "Enhancing Indoor Air Quality", while section 4,

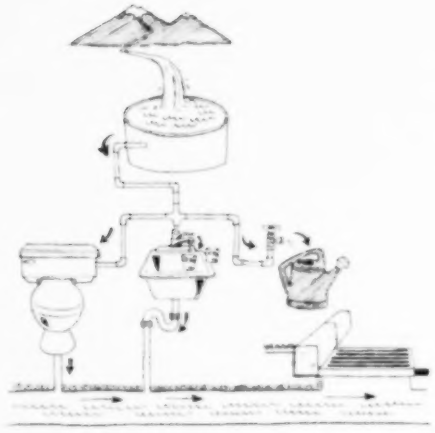
"Enhancing Environmental Performance", looks at site planning, materials selection, solid waste, water, landscape practices and noise. Section 5, "Enhancing Accessibility", discusses flexibility in site and circulation, dwelling unit layout and additional unit features.

The guide concludes with section 6, "Green Infrastructure". This section addresses different types of infrastructure systems, including storm water, liquid waste, potable water, energy, solid waste, and transportation and communication systems, plus it discusses management and financing strategies.

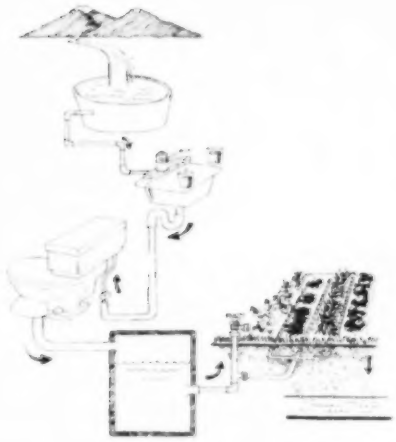
Conclusions

Healthy High-Rise is an excellent resource for anyone wanting ready access to concise, practical information about improving multi-unit or high-rise residential building performance. It identifies key areas that need to be considered and provides insight on a considerable range of topics, both the issues and solutions. For those interested in more detailed information on a given topic, the guide is a handy reference to other sources.

Figure 3. Improved systems approach



Inappropriate Water Use, circa 2000



Cascading Water Use, circa 2050

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Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

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